Biogeochemistry of a late coccolithophorid bloom at the continental margin of the Bay of Biscay

J. Harlay[1], C. De Bodt[1], Q. d'Hoop[1], N. Roevros[1], A.V. Borges[2], B. Delille[2], K. Suykens[2], N. Van Oostende[3], K. Sabbe[3], J. Piontek[4], N. Händel[4], S. Schmidt[5], S. Groom[6], A. Engel[4], and L. Chou[1]

[1] Laboratoire d'Océanographie Chimique et Géochimie des Eaux (LOCGE), Université Libre de Bruxelles (ULB), B-1050 Brussels, Belgium
[2] Unité d'Océanographie Chimique, Université de Liège (ULg), B-4000, Liège, Belgium
[3] Protistologie & Aquatische Ecologie, Universiteit Gent (UG), B-9000, Gent, Belgium
[4] 'Global change and the future marine carbon cycle', Alfred Wegener Institute for Polar and Marine Research (AWI), Bremerhaven, Germany
[5] Environnements et Paléoenvironnements Océaniques (UMR 5805 EPOC – OASU), Université Bordeaux 1, F-33405 Talence, France
[6] Remote Sensing Group, Plymouth Marine Laboratory, Plymouth, United-Kingdom

jharlay@ulb.ac.be

Background:

Coccolithophores, among which ***Emiliania huxleyi*** is a major species, are minute **phytoplantonic organisms** capable of producing large amounts of **calcium carbonate** as well as **particulate organic carbon (POC)**. The presence of abundant suspended minute **calcite** plates in the water column results in a change in seawater optical properties leading to a **high reflectance (HR)**, which can be observed from space by remote sensing. Their contribution to **carbon cycling** in the ocean is not only linked to **primary production** and **calcification**. Coccolithophores also produce large amounts of **transparent exopolymer particles (TEP)** that may lead to the formation of **marine snow** by aggregation of suspended material in the water column. The formation of **macro-aggregates**, combined with the ballast effect of calcite, makes them good candidates for the **export and sequestration of carbon** in the ocean. Massive coccolithophorid blooms occur each year at the continental margin of the Bay of Biscay between April and July. Our study reports the relative importance of processes, such as primary production, calcification, respiration rates and air-sea CO_2 fluxes, measured during a campaign in early June 2006 . We compare the patterns of various parameters, including TEP and the bacterial community structure at various sampling stations displaying different stages of the bloom.

During an **interdisciplinary biogeochemical study** carried out in early June 2006 a huge **coccolithophorid bloom,** characterized by **HR** patches located at the continental margin of the Bay of Biscay was sampled. **Low nutrient** levels and a **thermal stratification** down to 40-60 m depth were observed. Sea surface temperatures ranged from 13°C to 15°C during the cruise.

Rates of **primary production** and **calcification** (Fig. 1) were lower within the HR patch than outside, which probably indicates a **later stage of the bloom**.

The intense calcification has also reduced the surface seawater **total alkalinity** by up to 26 µmol kg^{-1} (see Suykens *et al.* Poster session PS007). **Pelagic respiration rates** were in the same range or exceeded those of primary production, which increased at stations 1bis and 4bis revisited one week later. The investigated area was however a **net sink for atmospheric CO_2**, due to phytoplankton activity, as shown by the negative air-sea CO_2 flux in Fig. 1.

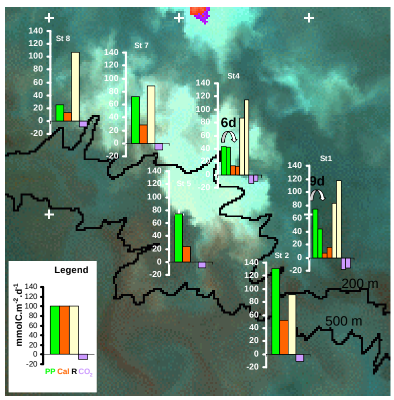


Figure 1: C uptake in organic (green) and inorganic (orange) matter (^{14}C incorporation technique). Respiration rates (O_2 consumption, yellow) converted into C units using a conversion factor C:O_2 = 1. Calculated air-sea CO_2 flux (based on measured air-sea CO_2 gradient, purple); negative values correspond to a flux from air to sea. Isobaths 200 m and 500 m are indicated by black lines. Reflectance based on satellite image taken on 5 June 2006.

The **C:N ratio** in particulate organic matter (Fig. 2) was significantly different from the Redfield ratio, suggesting a decoupling between dissolved nutrients dynamics and carbon cycling towards **carbon excess production** in surface.

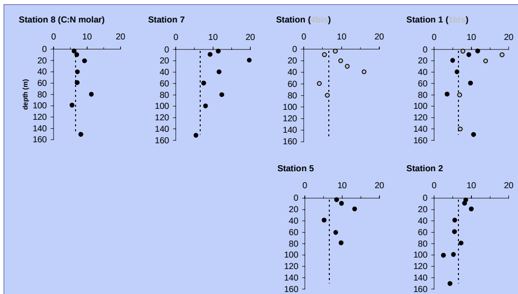


Figure 2: C:N molar ratio in particulate organic matter. The dashed line indicates the Redfield C:N ratio.

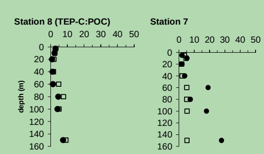
Our results provide an original dataset on **TEP** within a natural population of the coccolithophore *Emiliania huxleyi*, during its exponential and calcifying growth phases.

Two methods were used to characterize the TEP in this study. **TEP_{micro}** refers to the microscopic enumeration and size distribution of particles while **TEP_{color}** corresponds to colorimetric measurements calibrated with gum Xanthan.

TEP_{color} could reach values exceeding 2000 µgXeq l^{-1} in surface at St 2 and St 1bis, corresponding to the higher range of concentrations observed during oceanic blooms.

The study of the **size spectrum** of TEP_{micro} indicated that the TEP (0.1-1 ppm volume fraction) were small and equally distributed over the depths analyzed.

When converted into carbon units and compared to POC (Fig. 3) the two approaches give similar results and **TEP-C** could contribute to 1-5 % of the POC. Discrepancies may reflect either changes in chemical composition of TEP (polysaccharides, non-TEP inclusions), or changes in the intrinsic structure of TEP (aggregation). The potential for particle aggregation can be observed at depth at St 7, where TEP_{micro}-C:POC increased independently from TEP_{color}-C. In contrast, the individual cells, coated with highly stainable polysaccharides, probably contribute to the bulk TEP_{color}-C in surface at St 2.



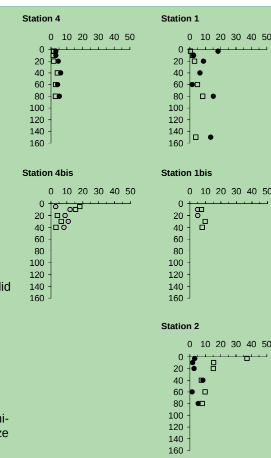


Figure 3: Contributions to POC in % of TEP_{micro}-C (solid circles) and TEP_{color}-C (open squares).

TEP-C was estimated based on two approaches:

$$TEP_{color} - C = 0.0033 \times TEP_{color}$$

$$TEP_{micro} - C = 0.25 \times 10^{-6} \sum_i n_i r_i^D$$

where D is the fractal dimension estimated from a semi-empirical relationship of the spectral slope of size distribution $D = (64 - \delta)/26.2$

Analysis of the **pigment composition** by HPLC indicated that St 1, St 2 and St 3 were dominated by coccolithophores (diagnostic pigment 19'-hexanoyloxyfucoxanthin, Hex-fuc). The stations within the HR patch were diatom-dominated (*Rhizosolenia* spp.).

The **particle-associated** and **free-living bacterial** fractions showed a clear distinction in their **community structure** (Fig. 4). Both the free-living and particle-associated bacterial communities displayed a **different structure inside or outside the HR patch**, but this distinction was more pronounced in the particle-associated fraction.

We hypothesize that the observed differences are mostly due to the chemical properties of the aggregates produced by coccolithophores and that the bacterial community plays an important role in the formation of marine snow and the export of C during a coccolithophorid bloom in the continental margin environment.

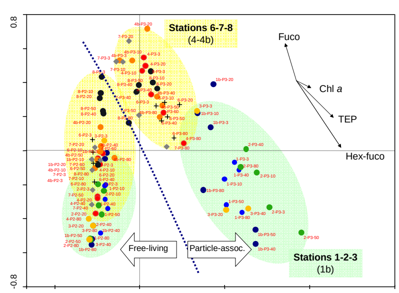


Figure 4: Principal Components Analysis of the **bacterial community structure** (DGGE) with some plotted environmental variables (TEP, Hex-fuco, Fuco, Chl *a*). Stations are denoted by the first number in the sample code, P3 refers to the "particle-associated" or >3 µm bacterial size fraction, P2 to the "free-living" or <3 µm bacterial size fraction, the last numbers refer to the depth. The areas highlighted in green show the stations located outside the HR patch, while the yellow ones regroup the stations located within the HR patch.

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